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Comparison between "underway" and "on station" acoustic measurements made during bottom trawl surveys.

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It becomes in many cases, routine, to collect acoustic data during bottom trawl surveys, both during and between trawls providing "on station" and "underway" acoustic data. Still, the combination of trawl and acoustic data is not operational and could represent a cost-effective way of improvement: bottom trawl survey use samples taken from very small areas (say 2 n.mi.) as representative of much larger areas (the statistical rectangles) while an acoustic transect from one trawling station to the next one, covers a 20-30 n.mi. strip. This study uses 3 different surveys (Norwegian acoustic and bottom trawl survey for cod and haddock in 2000; IBTS (France) in 2002; Northern Irish bottom trawl survey in 2000) where "on station" data are integrated over the trawling sections while "underway" data are regularly integrated over 1, 0.5 or 0.1 n.mi.

The objective of this exploratory data analysis is to evaluate the consistency between "underway" and "on station" acoustic data. Experimental means and variances of NASC values are first presented. Acoustic observations being autocorrelated, we analysed the consistency between acoustic data using geostatistical tools. The spatial structures (i.e. variograms) of the 'underway' acoustic data indicate that fish assemblages are autocorrelated in space. If the variograms of "underway" and of "on station" data indicate the same large distance structures, the "underway" acoustic data provide the opportunity to observe short scale structures that are smaller than the interstations distances. These structures appears as nugget effect on "on station"variograms and may explain why very few structure are observed sometimes "on station".

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Introduction

It becomes in many cases, routine, to collect acoustic data during bottom trawl surveys, both during and between trawls providing *a priori* two different types of acoustic data : "on station" and "underway" acoustic data. The combination of trawl catches and these two acoustic variables is not operational and could represent a cost-effective ways of improvement of the estimations of indices of abundances. As a matter of fact, bottom trawl surveys use samples taken from swept areas/volumes, that is from very small areas (few nautical miles long x tens of meter large that is of the order of magnitude of less than a 1 n.mi.^{2}), as representative of statistical rectangles that are much larger (of the order of magnitude of several 100 n.mi.^{2}). The use of acoustic transects from one trawling station to the next one extends significantly the available information.

This work is part of the EC project CATEFA (acronym for Combining Acoustic and Trawl data for Estimating Fish Abundance) started in October 2001. The present communication covers the preliminary steps based on the exploratory data analysis of 3 different surveys : Norwegian acoustic and bottom trawl survey for cod and haddock in 2001, International Bottom Trawl Survey (IBTS) with a focus on France leg performed in winter 2002 and Northern Irish bottom trawl survey in 2000. The objective of this exploratory data analysis is to evaluate the consistency between "underway" and "on station" acoustic recordings for modeling both bottom trawl and bottom acoustic data for (routine) abundance estimation.

Data preparation

Acoustic data (threshold at –70dB), both "underway"and "on station" have been collected or replayed according to different depth layers (Figure 1) : ten layers of 1 m referenced to the bottom and, as many as necessary layers of 10 m to reach the surface (bottom or surface referenced).

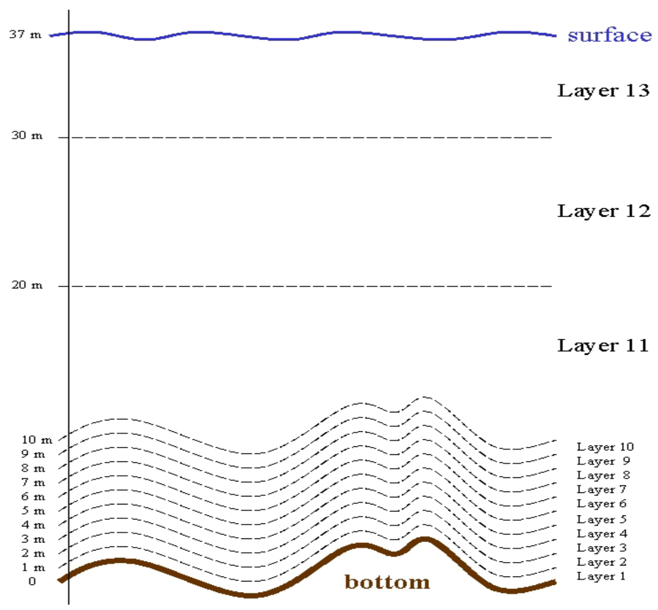


Figure 1. Definition of the acoustic depth layers.

Scrutinization of the bottom layers, directly on board during the survey or when replaying the datasets, allows for correcting the echoes associated to bottom detection. Criteria and tools to perform this correction together with the scale of the data used (samples data, i.e. V telegram, Q telegram, ping data, etc) vary according to countries and experts. In particular, fixed and variable backsteps have been applied. However, the objective was to chose the closest backstep (bottom offset) compatible with minimising breakthrough. Still, and despite this bottom correction, acoustic data present extremely asymmetric distribution with extremes values reaching several tens of thousand of $m^2 \cdot n.mi.^{-2}$ (Table 1).

"On station" data were integrated over the trawling sections. The starting and ending trawl coordinates have been used to estimate the towed distances in each survey. Their geographical representation and their histogram (Figure 2) indicate how variable they are despite the fact that they ought to be standardised. The mean towed distances are : 1.6 n.mi. for Norway, 2.75 n.mi. for Ireland with a target tow distance of 3 n.mi. while a set of experimental small tows were performed that year in the southern part of the survey area, and 1.8 n.mi. for France.

"Underway" data were regularly integrated over 1 n.mi. (Norway), 0.5 n.mi. (Ireland) and 0.1 n.mi. (France). "On station" data represent then on average 1.6, 6 and 18 times longer intervals than the "underway" ones respectively. This is known to impact the level of variability and makes direct comparison difficult. "Underway" data have then been combined (i.e. regularised) to the nearest possible distance compatible with the mean towed distance, that is 1 n.mi. for Norway (it was not worth to go for a 2 n.mi. not significantly less different from 1.6 n.mi. than the actual ESDU) , 3 n.mi. for Ireland (groups of 6 elementary ESDUs) and 1.8 n.mi. for France (groups of 18 elementary ESDUs).

Table 1 allows to follow the impact of the data preparation process on basic statistics such as the mean, the maximum and the coefficient of variation in the case of IBTS 2002 data (french leg). This is the case where the regularisation step is expected to have largest impact due to large difference between "underway" and "on station" ESDU. One can see the decrease of the variability (cv) due to the regularisation. On average over le first 10 layers of 1 meter high, the CV decreases by 0.8. It decreases even more substantially for layers 11, 12 (10 m high) and 13 (from 10 to 1 m high).

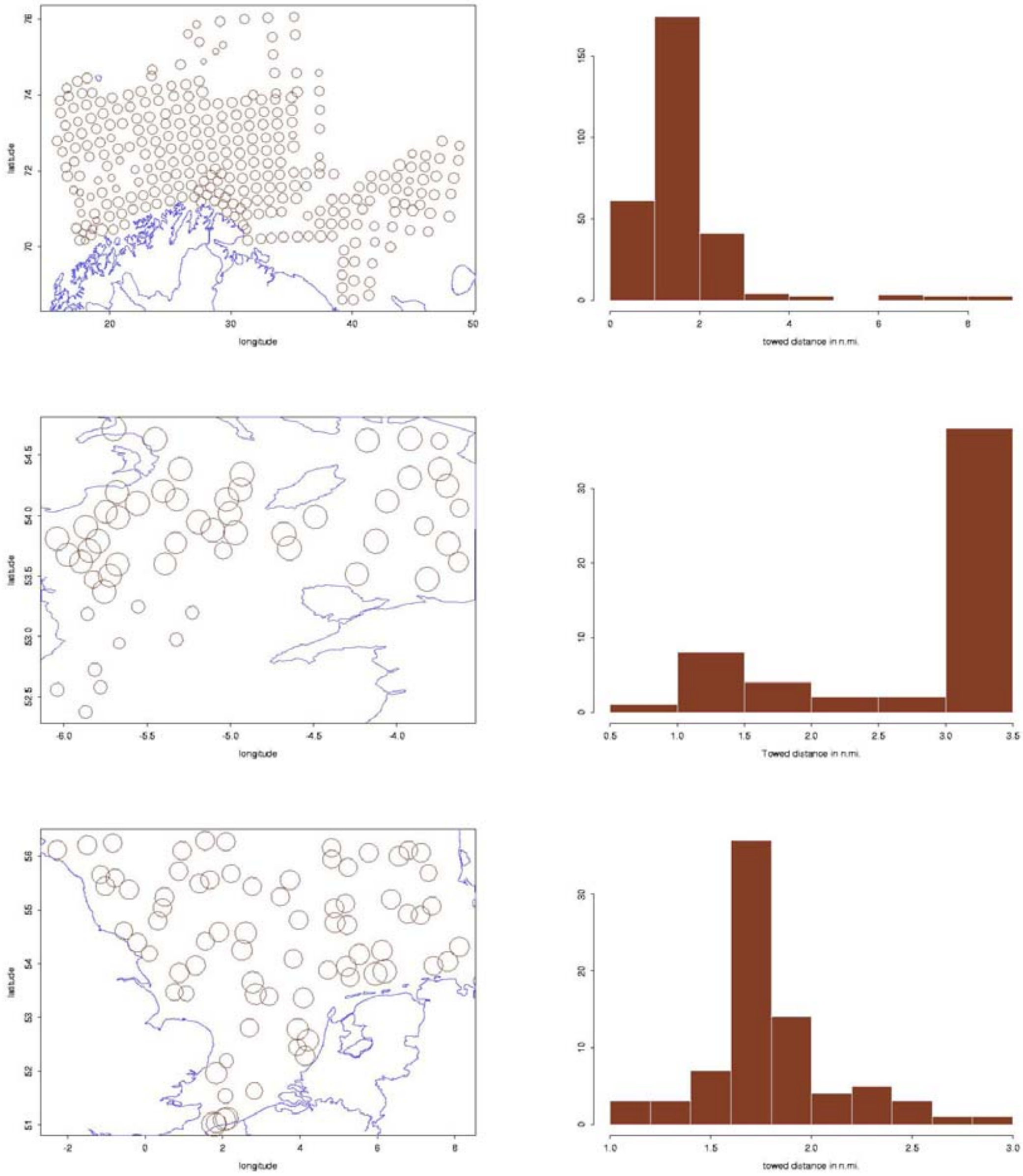


Figure 2. Tow distances in nautical miles for each survey.
Left column : Geographical representation with circles'surface proportional to the tow distances. *Right column* : Histograms of the corresponding values.
First line : Norwegian survey, 2001. *Second line* : North Irish bottom trawl survey 2001. *Third line* : IBTS - France, 2002.

Table 1. Mean, maximum (units are $m^2 \cdot n.mi.^{-2}$) and coefficient of variation (cv) for "underway" acoustic data per depth layers (IBTS 2002 french leg). Comparison between raw data integrated over 0.1 n.mi. (raw), and regularised data over 1.8 n.mi. ESDUs (regularised).
(*) First layer, i.e. bottom layer, without backstep.
(**) First layer, i.e. bottom layer, with backstep.

	mean		max		cv	
layer	raw	regularised	raw	regularised	raw	regularised
1*	45.83	14.75	22853.56	142.65	10.13	1.22
1**	38.38	8.73	22825.8	119.05	12.02	1.66
2	11.77	4.69	13726.57	92.14	17.07	2.17
3	7.09	3.44	16372.81	40.06	26.77	2.11
4	10.51	2.83	56194.95	51.32	59.89	2.19
5	3.23	2.4	2619.28	55.48	10.21	2.55
6	2.58	2.17	375.55	57.3	4.53	2.83
7	2.76	2.1	856.49	58.91	6.29	2.86
8	3.9	2	5509.03	62.01	17.75	2.92
9	3.78	1.86	3629.58	52.74	14.64	2.81
10	5.59	1.87	13086.54	58.19	28.25	2.69
11	51.6	30.68	142528.42	1753.72	32.58	4.07
12	16.79	16.66	20290.92	1535.37	21.79	6
13	3.41	3.35	1495.67	99.33	7.19	3.12
1-5	70.98	22.09	77502.98	244.23	14.54	1.72

Basic description and statistics

Over the three surveys used for this study, sampling strategies are different (Figures 3, 4 and 5). Norway follows a regularly scheme while IBTS survey and North Irish bottom trawl survey are random stratified (one random point per statistical rectangle). Moreover, for IBTS and North Irish bottom trawl, no recording is performed at night. “Underway” acoustic data are then available by batches of transects, i.e. the transects that join the trawl stations performed during one particular day.

Numbers of “on station” observations (Table 2) ranges between 54 to 299 while the numbers of “underway” observations ranges between 184 to 7665 after they have been regularised. In this regards, the North Irish survey presents lesser statistical conditions for the analysis than the norwegian survey, especially when considering the strong skewness of the data.

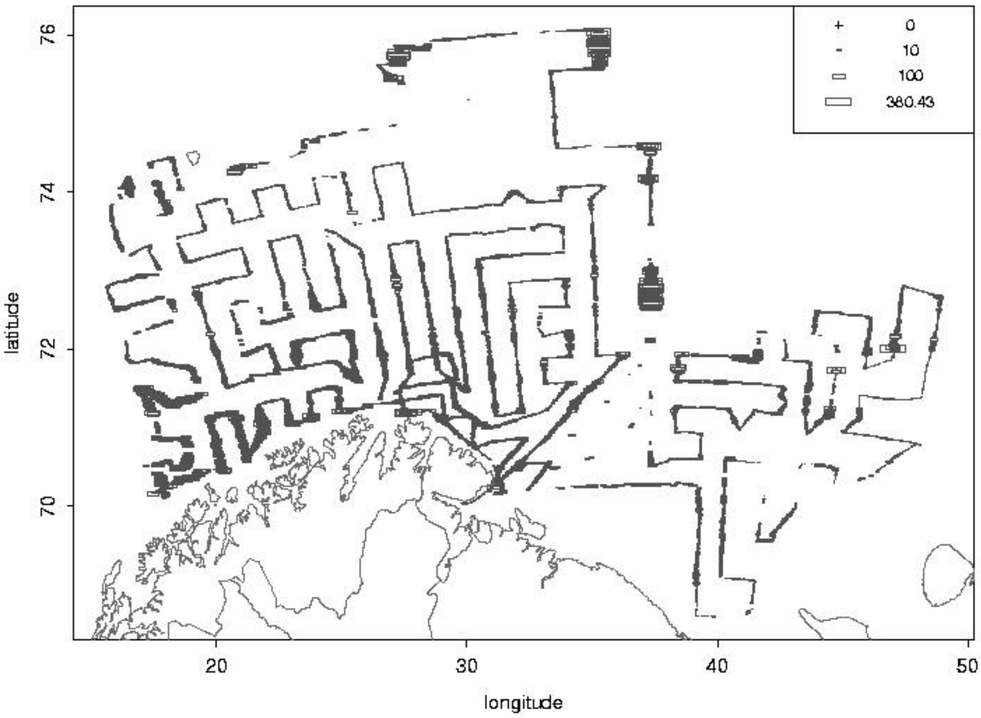
Table 2. Numbers of “underway” and “on station” observations before and after regularisation.

	Norway	North Ireland	France
underway NASC before regularization	7665	1459	7982
underway NASC after regularization	7665	184	439
on station NASC	299	54	77

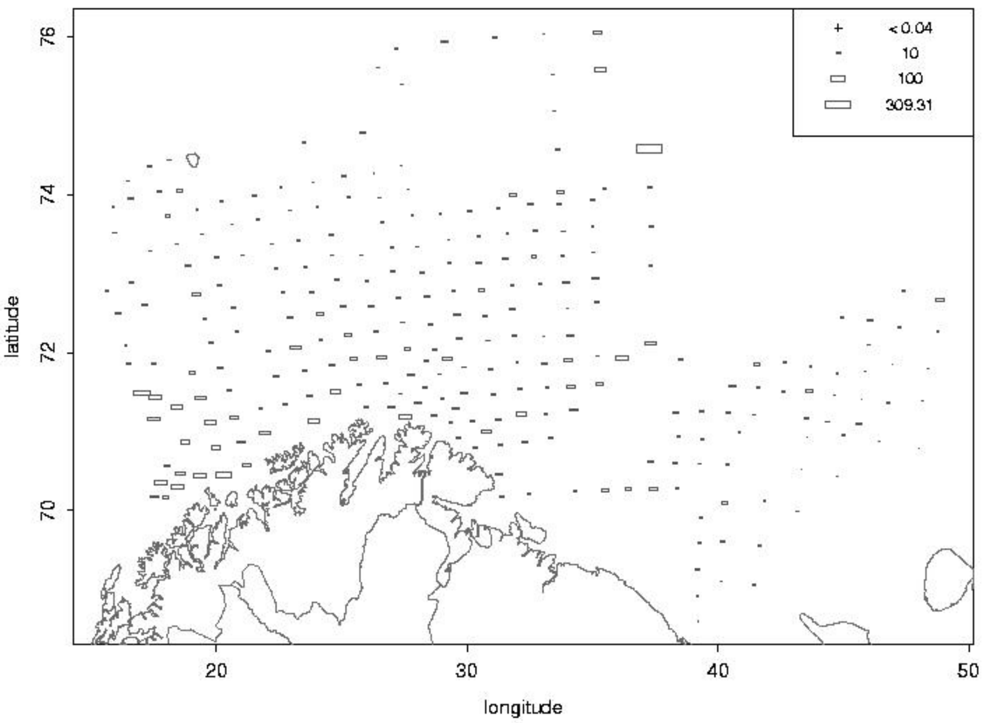
Very large trends, i.e. poor versus dense areas, as observed from either the “underway” or the “on station” acoustic data are similar different (Figures 3, 4 and 5). However, a simple visual inspection of the geographical representations of the survey data, allows to anticipated some difficulties, like :

- Large values are observed at the border of the survey area in Norway (Figure 3a)
- Small areas with large “underway” values but small “on station” ones (Figures 5a and b for instance)
- Large NASC values surrounded by (very) small ones

The first 10 layers cover always the 10 meters above the bottom but represents variable proportions of the entire water column as the mean water depth varies from 40 m for IBTS survey, to 60 m for North Irish survey and to 280 m for the norwegian one.

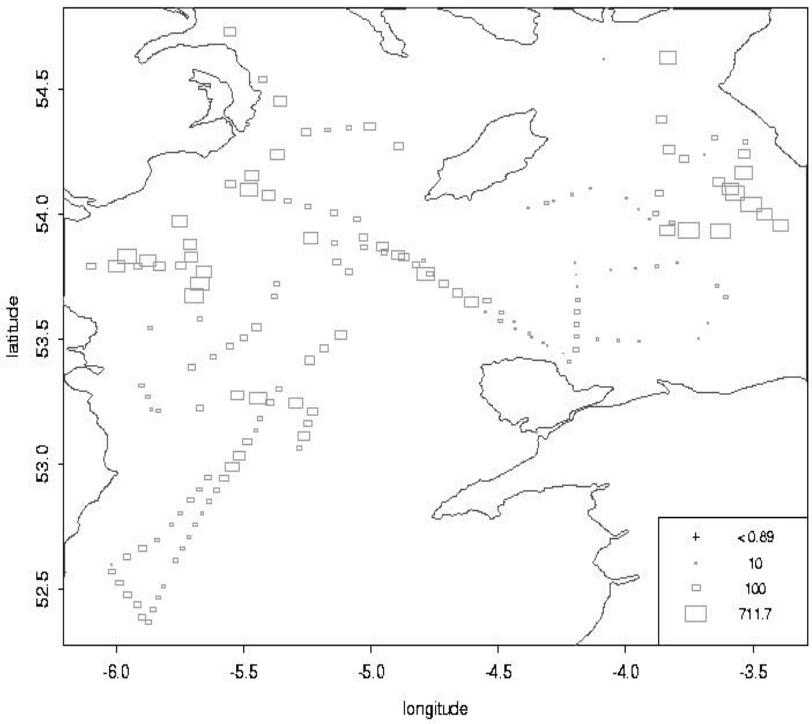


(a) “underway” acoustic data.

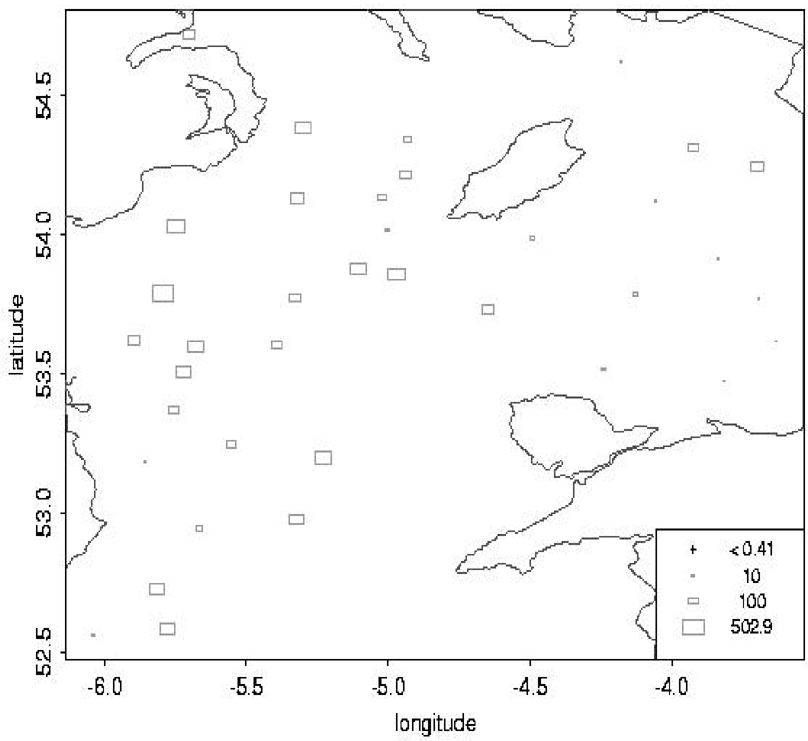


(b) “on station” acoustic data.

Figure 3. Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). Norway 2001. Data larger than 100 $m^2 \cdot n.mi.^{-2}$ removed.

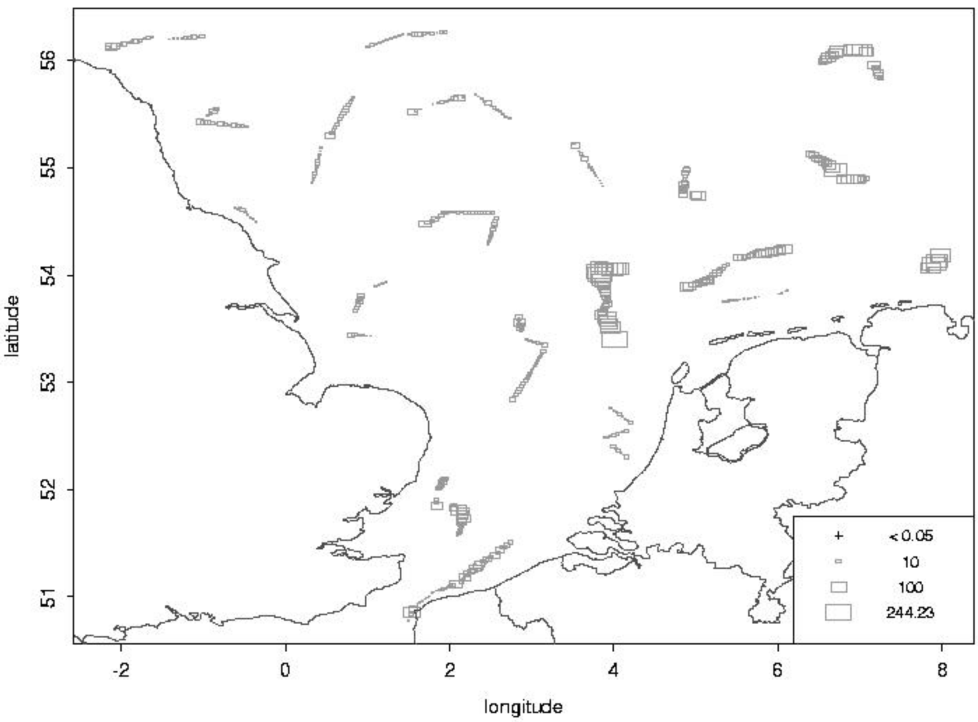


(a) “underway”acoustic data regularised to 3 n.mi .

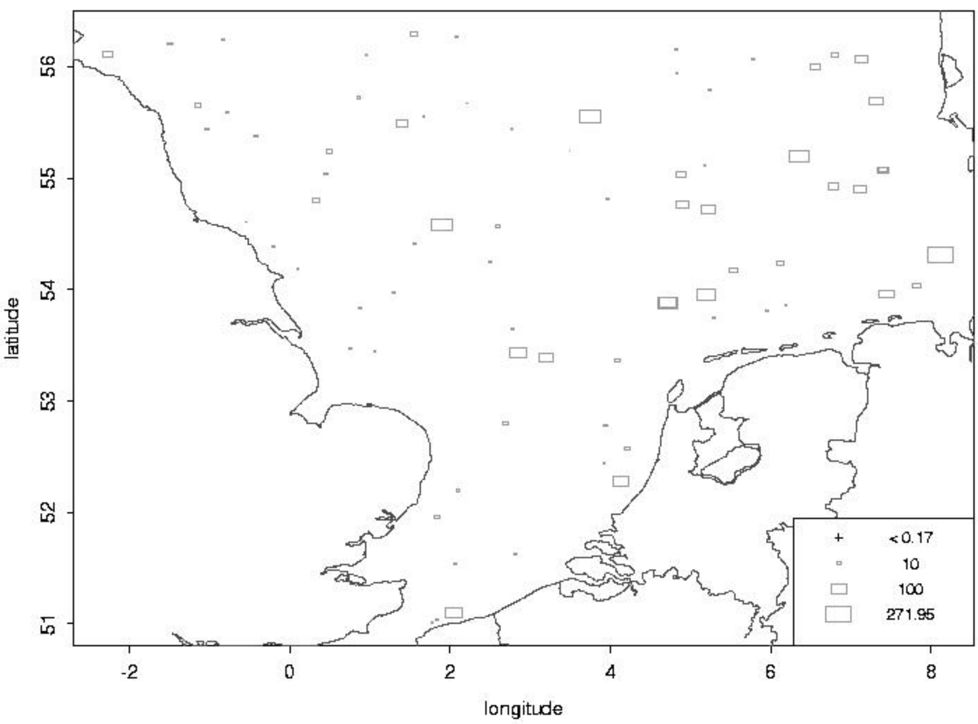


(b) “on station”acoustic data..

Figure 4 Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). North Irish Bottom trawl survey 2001. Data larger than 200 $m^2 \cdot n.mi.^{-2}$ removed.



(a) “underway”acoustic data regularised to 1.8 n.mi .



(b) “on station”acoustic data.

Figure 5 Sampling scheme and proportional representation of the sum of the first 5 acoustic layers (layer1-5). IBTS 2002. French leg. Data larger than 200 $m^2 \cdot n.mi.^{-2}$ removed.

Mean NASC and NASC variance per layer

Consistency between “on station” and “underway” have been first tested comparing the mean and the variance of the regularised NASC values per layers and per survey (Figure 6). Mean NASC and NASC variance are very consistent for the norwegian survey. Variances are slightly larger for “underway” data which could be due the fact that “on station” ESDUs are, on average, 1.6 times larger than “underway” ESDUs, and are thus expected to be less variable.
Except for the first layer mainly, i.e. the bottom layer, consistency between “on station” and “underway” is also very large for IBTS-France survey.
For North Irish survey, acoustic recorded during trawls are, on average, an order of magnitude larger than those recorded between trawls. Acoustic were then replayed extracting energies associated with well identified pelagic schools. As a matter of fact fish assemblages in the Irish Sea at the survey period was dominated by such schools. With pelagic (mainly clupeoids) removed, mean NASC and NASC variance of “underway” and “on station” data are consistent. It is speculated that this may have to do with the fish sinking behavior during the trawl operations (relative shallow waters and predominance of pelagic species in the studied area). Together with the fact that the low number of “on station” data may lead to highly variable estimates of the mean NASC values, this sinking behavior may also be advocated to explain IBTS-France results for the first bottom layers.

Omnidirectional variograms per layer

The other tool used to test for consistency between “underway” and “on station” acoustic data was the variogram (i.e the spatial structure). To this end, omnidirectional variograms per layers have been computed for the first 10 bottom layers. Distance lags have been set to the respective ESDU sizes. As the experimental variance of each layer departs from one layer to the others, variograms have been normalised to their variance so that their sills, if any, fluctuate around 1 whatever the experimental variances. The spatial structures are then compared relatively to their levels of variance.
“Underway” and “on station” experimental structures match very much for Norway data (Figure 7, first line). Both “underway” and “on station” data indicate a well established spatial structure at 200 n.mi.. In addition, “underway” acoustic data provide a description of the structure for distances between 1 and 20 n.mi., i.e. below the inter sample distance (Figure 8a).
Eventhough the variograms are more chaotic, similar results are observed for IBTS-France 2002 data (Figure 7, fourth line), both sets of variograms indicating the same increasing trend. The low, well structured part of the “underway” variograms at distances smaller than 25 n.mi. (Figure 8b), together with the sharp fluctuations observed beyond, may be due to the fact that “underway” data are available by batches of 3 or 4 interstations transects, each batch being 30 n.mi. apart from each others (Figure 5a).
Variograms obtained for the North Irish survey, with or without the pelagic schools, do not show similar consistency between “underway” and “on station” data (Figure

7, second and third line). A structure is observed for the “underway” recordings while no clear structure is observed when using acoustic data recorded during the tows.

For IBTS- France survey and the North Irish one, the number of “on station” acoustic data is quite small with regards to the skewness of the distribution. This partly explains the level of the flucutations of the experimental variograms.

“Underway” data makes it possible to observe short scale structures. For Norway, a small scale structure of 5-6 miles appears (Figure 8a). Such a structure is not accessible with the “on station” data which are 20 n.mi. apart and appears as a nugget effect on the corresponding variogram. The situation is less clear for IBTS 2002 data as NASC values near the bottom are smooth in space (low nugget effect) with a structure of 15 n.mi. while upper layers seems to have a shorter structure (around 5 n.mi.). But still structures

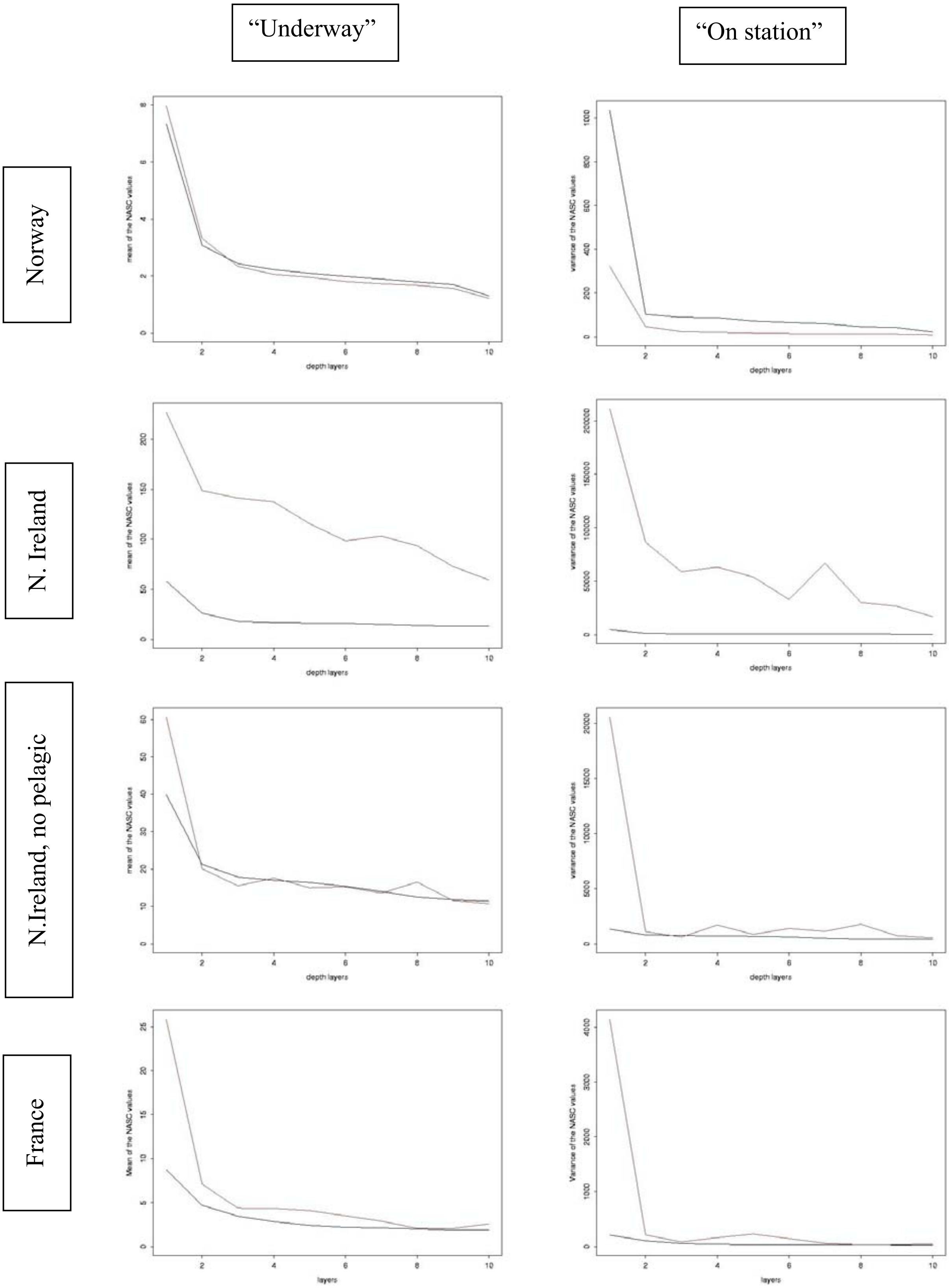


Figure 6. Mean (*left column*) and variance (*right column*) of NASC values per layers. The x-axis represent the layers' number.
Black line : Underway values. *Brown line* : On station values.
First line : Norway, 2001. *Second line* : Ireland 2001. *Third line* : Ireland 2001 with clupeoids schools removed. *Fourth line* : IBTS-France 2002.

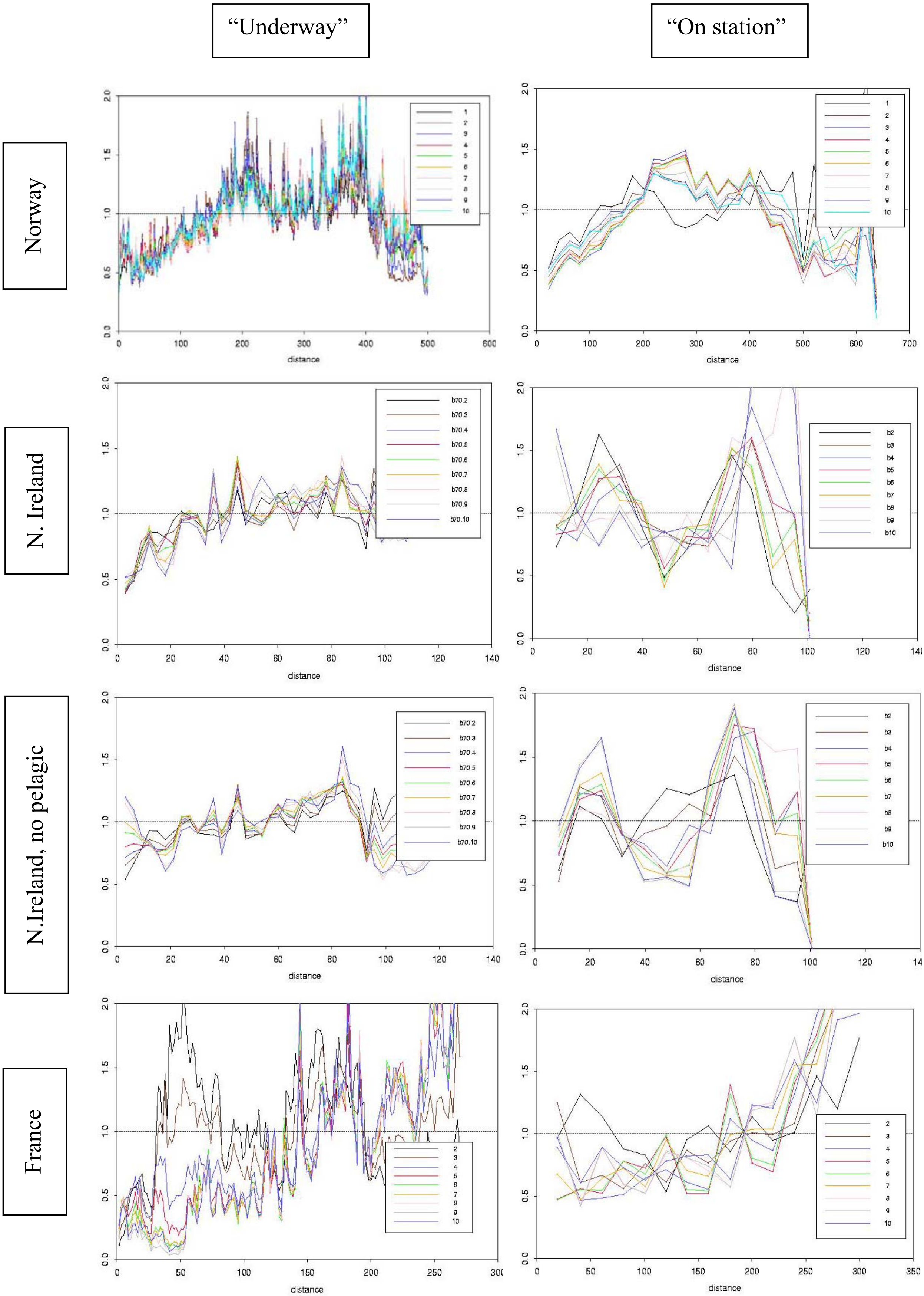
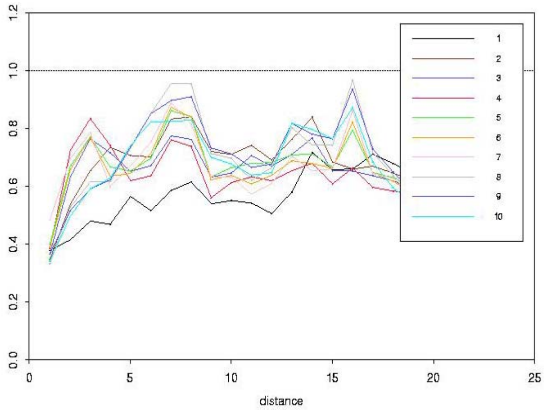
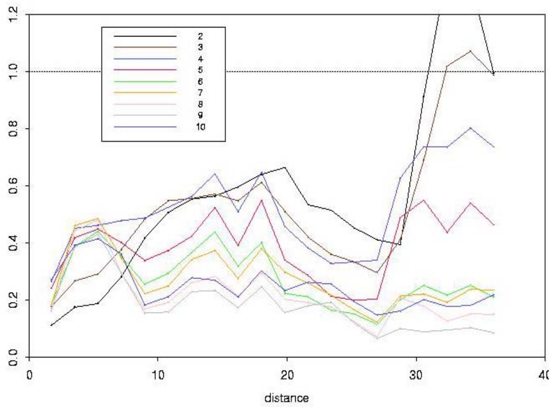


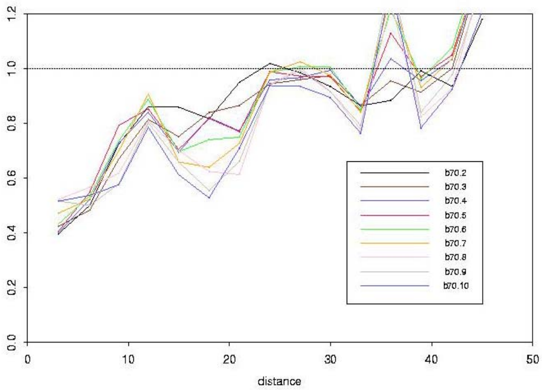
Figure 7. Normalised variograms for the first bottom layers. Distances are in n.mi.. *Left* : "Underway" regularised data. *Right* : "On station" data.
First line : Norway, 2001. *Second line* : Ireland 2001. *Third line* : Ireland 2001 with clupeoids schools removed. *Fourth line* : IBTS-France 2002.



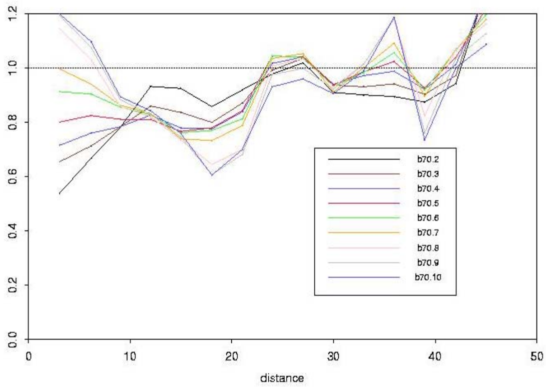
(a) Norway



(b) IBTS-France



(c) N. Ireland



(d) N. Ireland, no pelagic

Figure 8. Same as Figure 7, with a zoom on short distances for regularised "underway" acoustic data. (a) Norway, 2001. (b) IBTS-France 2002. (c) Ireland 2001. (d) Ireland 2001 with clupeoids schools removed.

Conclusions

These preliminary results indicate that there is a potential in these surveys for using both "underway" and "on station" acoustic data. Still, the most relevant variable to use is sometimes questionnable and area specific. For instance, the question of mixing or not the pelagic schools in the data set is opened with no clear answer.

In most cases, "underway" and "on station" acoustic data appear to be consistent and show interpretable and usable spatial patterns. The "underway" data provide short scale description when "on station" data mainly concern medium or long distance structures. So, for favorable cases, "underway" data are not only compatible but complementary to "on station" ones and could be used when interpolating between data points, which is what one implicite do when building an index of abundance.